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# RELATIONS OF WINTERING CANVASBACKS TO ENVIRONMENTAL POLLUTANTS—CHESAPEAKE BAY, MARYLAND

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Canvasbacks (*Aythya valisineria*) winter on many bays and estuaries that are polluted with a variety of toxic chemicals; moreover, some birds are exposed to contaminants along migration routes. Canvasback numbers have fluctuated widely from year-to-year, and in some years reproductive success has been poor even with favorable conditions on the breeding grounds. Poor success has been attributed to high mortality rates for immatures and adults, habitat and range reduction, and increased nest predation (Trauger 1974). In addition, environmental contaminants may influence success, since elevated levels of some chemicals in tissues and eggs may have adverse effects on reproduction and survival of birds (Stickel 1973).

Chesapeake Bay is the principal wintering area for Canvasbacks (Bellrose 1976). Since 1972, biologists at the Patuxent Wildlife Research Center have been studying Canvasbacks collected from the Bay to determine levels of organochlorine pesticides, polychlorinated biphenyls (PCB's), and selected heavy metals in tissues, eggs, and food items. In this paper we report the residues of environmental pollutants in tissues of Canvasbacks and their food items from Chesapeake Bay, Maryland, and discuss their relation to possible adverse effects on Canvasback populations. Residues of organochlorines and mercury in Canvasback eggs are reported elsewhere (Stendell et al. 1977).

## METHODS AND MATERIALS

The Migratory Bird and Habitat Research Laboratory collected Canvasbacks from Chesapeake Bay, Maryland, during the winters of 1973, 1975 and 1976 for analysis of gastrointestinal (GI) tracts to determine food habits. We obtained the carcasses for chemical analysis from these collections. Samples of Canvasback food items (clams) from Chesapeake Bay also were collected. Birds collected in 1973 were skinned and those collected in 1975 were plucked and the carcasses were analyzed for organochlorines. Prior to analysis, the GI tracts, feet, and beaks were removed. Carcasses were homogenized and a portion of each homogenate was analyzed for organochlorine residues at the Patuxent Wildlife Research Center. Residues in 5% of the samples were confirmed with a gas chromatograph/mass spectrometer. Limits of quantification were 0.1 ppm for organochlorine pesticides and 0.5 ppm for PCB's on a wet-weight basis. Analytical procedures we used for organochlorines are described in detail by Cromartie et al. (1975).

Canvasback tissues analyzed for heavy metals included: livers, 1973; livers, kidneys and wingbones, 1975; and livers and kidneys, 1976. Food samples (clams) also were analyzed for selected heavy metals. All heavy metal analyses were done at the Environmental Trace Substances Research Center, Columbia, Missouri, by atomic absorption spectrophotometry using quantification limits of 0.01 ppm on a wet-weight basis for livers, kidneys and clams, and 0.5 ppm on a dry-weight basis for wingbones.

Data were log-transformed and tested for differences using Student's *t*-test. Residues are reported as arithmetic means ± standard errors; since geometric means were very similar, they were excluded from the tables.

## RESULTS AND DISCUSSION

*Organochlorines.*—Eighty-three % of the 1973 carcasses contained DDE, 62% contained PCB's, and 24% contained dieldrin; 99% of the 1975 carcasses contained DDE and PCB's, and 14% contained dieldrin (Table 1). Differences were detected in carcass residues between the collection periods; only DDE, dieldrin, and PCB's were found in some of the 1973 skinned samples whereas some of the 1975 plucked samples contained a variety of other organochlorines. The 1975 samples contained approximately 60% more DDE and PCB's than the 1973 samples; this difference suggests that a large percentage of the residues may have been present in the skin and attached adipose tissue of the 1975 plucked birds. There were no differences ($P > 0.05$) in carcass residue levels between sexes or ages.

Overall, DDE residues in Canvasback carcasses were low (Table 1), and comparable to the levels measured in control birds in 2 dietary experiments. Haegele and Hudson (1974) fed Mallards (*Anas platyrhynchos*) diets containing 40 ppm DDE for 96 days; 42 days after cessation of treated food, DDE residues in skinned carcasses averaged 33 ppm (wet weight). Eleven months after DDE exposure ceased, carcass residues averaged 9.6 ppm in treated birds and 0.5 ppm in control birds. DDE residues in plucked carcasses of Black Ducks (*Anas rubripes*) fed 10 ppm DDE for 7 months averaged 155 ppm (wet weight); residues in control carcasses averaged about 0.3 ppm (Longcore and Stendell 1977). Two years after exposure ceased, DDE residues in Black Duck carcasses had dropped to 12.2 ppm in males and 3.4 ppm in females. Thus, Canvasbacks from the Chesapeake Bay probably are exposed to low environmental levels of DDE since residues in their carcasses were similar to those found in carcasses of experimental controls.

Dieldrin residues averaged less than 0.2 ppm in Canvasbacks (Table 1). These levels are far below residues in skinned carcasses of Meadowlarks (*Sturnella magna*) (4 ppm) and aquatic birds (9 ppm) found dead in areas treated with dieldrin or aldrin (Stickel et al. 1969, Flickinger and King 1972). Carcasses of Japanese Quail (*Coturnix coturnix japonica*) fed 10 ppm dieldrin for 4.5 months contained an average of 23 ppm (Stickel et al. 1969). Ruddy Duck (*Oxyura jamaicensis*) carcasses from the Delaware

TABLE 1

ORGANOCHLORINE RESIDUES (PPM, WET WEIGHT) IN CANVASBACK CARCASSES FROM CHESAPEAKE BAY, MARYLAND

| Chemical | Year[1] | N[2] | $\bar{x} \pm SE$[3] |
|---|---|---|---|
| DDE | 1973 | 24 | 0.36 ± 0.03 |
| | 1975 | 112 | 0.56 ± 0.06[a] |
| DDT | 1973 | | ND[4] |
| | 1975 | 7 | 0.18 ± 0.01 |
| DDD | 1973 | | ND |
| | 1975 | 5 | 0.11 ± 0.00 |
| Dieldrin | 1973 | 7 | 0.19 ± 0.03 |
| | 1975 | 16 | 0.19 ± 0.03 |
| PCB's[5] | 1973 | 18 | 1.5 ± 0.31 |
| | 1975 | 112 | 2.7 ± 0.21[a] |
| Toxaphene | 1973 | | ND |
| | 1975 | 2 | 0.17 ± 0.01 |
| *cis*-chlordane | 1973 | | ND |
| | 1975 | 9 | 0.19 ± 0.01 |
| *trans*-nonachlor | 1973 | | ND |
| | 1975 | 11 | 0.14 ± 0.01 |
| Oxychlordane | 1973 | | ND |
| | 1975 | 5 | 0.12 ± 0.01 |
| Hexachlorobenzene | 1973 | | ND |
| | 1975 | 5 | 0.15 ± 0.03 |
| Heptachlor epoxide | 1973 | | ND |
| | 1975 | 6 | 0.11 ± 0.00 |

[1] Sample size was 29 in 1973 and 113 in 1975.
[2] Number of carcasses having detectable residues.
[3] Arithmetic mean ± standard error; all carcasses having detectable residues were used in calculating means.
[4] Not detected.
[5] Polychlorinated biphenyls quantified on the basis of Arochlor 1260.
[a] Residues between years significantly different ($P < 0.001$, Student's *t*-test, log transformed data).

River (White and Kaiser 1976) contained dieldrin residues (0.24 ppm) similar to Canvasback carcasses.

PCB's in Canvasback carcasses (Table 1) were relatively low when compared to levels in other species: levels in Ruddy Ducks (White and Kaiser 1976) were twice those in Canvasbacks and levels in some Great Cormorants (*Phalacrocorax carbo*) found dead were 150 times greater (Koeman 1973).

TABLE 2

HEAVY METAL RESIDUES IN TISSUES OF CANVASBACKS FROM CHESAPEAKE BAY, MARYLAND

| Tissue[1] | Year | Metal | N[2] | x̄ ± SE[3] |
|---|---|---|---|---|
| Liver | 1973 | lead | 29 | 0.25 ± 0.02[a] |
| | | cadmium | 29 | 0.59 ± 0.09 |
| | | copper | 29 | 59 ± 8 |
| | | zinc | 29 | 41 ± 3 |
| | | mercury | 10 | 0.24 ± 0.03 |
| | | chromium | 10 | 0.02 ± 0.00 |
| | 1975 | lead | 87 | 0.14 ± 0.01 |
| | 1976 | lead | 70 | 0.19 ± 0.02 |
| Kidney | 1975 | cadmium | 113 | 2.3 ± 0.16 |
| | 1976 | cadmium | 69 | 2.3 ± 0.23 |
| Wingbone | 1975 | lead | 78 | 7.8 ± 1.0 |

[1] Residues in liver and kidney are reported as ppm wet weight, and ppm dry weight in wingbone.
[2] Number of samples analyzed.
[3] Arithmetic mean ± standard error.
[a] Lead residues between 1973 and 1975, 1976 significantly different ($P < 0.01$, Student's $t$-test, log transformed data).

Canvasback eggs contained up to 29 ppm PCB's, but the potential effects of these elevated levels on Canvasback reproduction are not known (Stendell et al. 1977). Mallards fed 25 ppm PCB for 2 years showed no reproductive impairment (Heath et al. 1972). Similar levels fed to chickens severely impaired reproductive success (Lillie et al. 1974), and 3 ppm PCB in chicken eggs reduced hatchability (Scott et al. 1975). We found that DDE and PCB residues in Canvasback carcasses were significantly correlated (linear regression analysis, $r = 0.80$, df = 130, $P < 0.01$) as were DDE and PCB's in Canvasback eggs (Stendell et al. 1977).

Toxaphene, chlordane isomers, hexachlorobenzene, and heptachlor epoxide were present in a few 1975 Canvasback carcasses (Table 1). In all cases, residues were less than 0.3 ppm and are below levels suspected of causing problems in avian species. Endrin and mirex were not detected in Chesapeake Bay Canvasbacks.

*Heavy metals.*—Mercury residues in Canvasback livers (Table 2) were lower than those reported in livers of other field-collected waterfowl (Dustman et al. 1972, Krapu et al. 1973, Fimreite 1974) and only slightly higher than in livers of control birds in dietary experiments (Heinz 1976, Stickel et al. 1977). Cadmium ranged up to 11.6 ppm in Canvasback kidneys (Table 2) and mean residues in livers were identical to those reported for Ruddy Ducks from the Delaware River (White and Kaiser 1976). Kidneys of Mallards fed 2 ppm dietary cadmium contained an average of 2.9 ppm after 60 days (White and Finley 1978); these levels are similar to those found in kidneys of Canvasbacks. Two hundred ppm dietary cadmium produced kidney lesions and inhibited spermatogenesis in adult Mallards but no effects were detected in groups fed 2 or 20 ppm (White et al. 1978).

Overall, lead residues in Canvasback livers were relatively low (Table 2). Birds collected in 1975 had lower lead residues than birds collected in 1973 ($P < 0.02$). Lead levels were similar to those reported in livers of experimental birds (Finley et al. 1976a, Finley et al. 1976b). Dieter (1978) measured a lead-specific enzyme in the plasma of about 400 Canvasbacks; 12% of the sample exhibited less than half of the normal blood-enzyme activity indicating exposure to an elevated amount of lead. In a sample of 9 ducks with abnormal enzyme activity, residues of lead in the livers averaged 0.86 ppm (Dieter 1978). In our study, only 3% of the Canvasback livers contained more than 0.5 ppm lead.

While the residue in liver indicates current exposure to lead, the residue in avian bones indicates the history of exposure to lead from all sources including lead shot. Uptake of lead by bone is rapid and loss is slow. An elevated level (> 20 ppm) in wingbones of an immature bird indicates exposure to a high level of lead, most likely as shot (Longcore et al. 1974, Finley et al. 1976b, R. C. Stendell, unpublished data). Since the period of exposure of adults is longer than that of immatures, an elevated level in the bone of adults may result from exposure to shot during the current or past years or possibly to elevated levels of non-shot lead in the diet over an extended period.

Lead residues in our sample of 78 Canvasback wingbones ranged from 0.6 to 38.2 ppm. No Canvasback gizzards contained lead shot, although 6% of immature and 10% of adult wingbones contained greater than 20 ppm lead. However, there was no difference ($P > 0.05$) between wingbone lead levels of immatures and adults. The frequency of occurrence of shot in gizzards of immature waterfowl was significantly correlated to median wingbone lead levels and percentages of wingbones with greater than 20 ppm lead (White and Stendell 1977).

Chromium residues in Canvasback livers were low, but copper and zinc accumulated to levels higher than any of the other metals (Table 2). These levels were similar to those found in livers of Bald Eagles (*Haliaeetus leucocephalus*) and Ospreys (*Pandion haliaetus*) (S. N. Wiemeyer, unpublished data).

In past years the major food of Canvasbacks wintering on Chesapeake Bay was wild celery (*Vallisneria americana*) (Stewart 1962), but this plant has practically disappeared from the area, probably from increased turbidity

TABLE 3

HEAVY METAL RESIDUES (PPM WET WEIGHT) IN CANVASBACK FOOD ITEMS (WHOLE CLAMS) FROM CHESAPEAKE BAY, MARYLAND

| Species | Year | Metal | N(n)[1] | $\bar{x} \pm SE$[2] |
|---|---|---|---|---|
| *Rangia cuneata* | 1973 | lead | 6(150) | 0.37 ± 0.07 |
| | | cadmium | 6(150) | 0.06 ± 0.01 |
| | | copper | 6(150) | 3.99 ± 0.24 |
| | | zinc | 6(150) | 6.76 ± 1.00 |
| | | mercury | 6(150) | all t |
| | | chromium | 6(150) | 0.32 ± 0.07 |
| *Macoma balthica* | 1975 | lead | 3(426) | 0.56 ± 0.07 |
| | | cadmium | 3(426) | 0.05 ± 0.01 |
| *Macoma mitchelli* | 1975 | lead | 2(190) | 0.28 ± 0.06 |
| | | cadmium | 2(190) | 0.02 ± 0.00 |
| *Mya arenaria* | 1975 | lead | 3(370) | 0.30 ± 0.09 |
| | | cadmium | 3(370) | 0.10 ± 0.04 |
| *Mulinia lateralis* | 1975 | lead | 1(10) | 0.02 |
| | | cadmium | 1(10) | 0.02 |

[1] N(n) = numbers of pools (number of total individuals).
[2] Arithmetic mean ± standard error.
t = Trace residues less than 0.01 ppm.

and lessened salinity (Perry 1974). As a result Canvasbacks have changed to alternate food sources. Approximately 90% of the Canvasbacks' diet consists of small clams of several species (M. C. Perry and F. M. Uhler, unpublished data). Residues of heavy metals in clams collected in 1973 and 1975 are shown in Table 3. In general, cadmium and lead levels were similar in all species, but copper and zinc accumulated to higher levels in the clam, *Rangia cuneata*, than any of the other metals. Mollusks are known to accumulate high levels of certain metals even when exposed to low concentrations of those metals in the environment (Bryan 1971). Therefore, the relatively low metal residues in Chesapeake Bay clams probably reflect background contamination.

## CONCLUSIONS

Canvasback eggs (Stendell et al. 1977) and carcasses from the Chesapeake Bay generally contained low levels of organochlorine pesticides and PCB's. Experimental studies with other waterfowl species suggest that these residues are below levels known to have an adverse effect on avian reproduction and survival. A few samples, however, did contain amounts of DDE or PCB's that approximate the range in which adverse effects may be expected. Similarly, levels of mercury and cadmium are below known-effect levels. Lead residues in most birds were low, although elevated levels in wingbones of some birds indicated a history of past exposure to lead; Dieter (1978) found similar results in Canvasbacks by measuring plasma-enzyme levels in blood. Elevated, sublethal levels of lead may cause some physiological disturbances in birds but the potential effect on survival and reproduction are unknown, as is the significance of relatively high copper and zinc residues in Canvasback livers.

In addition, the effects that cumulative concentrations of toxic chemicals in birds might have on reproduction and survival are poorly understood. Birds with high contaminant burdens might be more susceptible to disease, hunting pressure or nest predation than birds with low levels.

## SUMMARY

Studies were conducted to determine the levels of environmental pollutants in Canvasbacks wintering on Chesapeake Bay, Maryland, and their food items, in 1973, 1975, and 1976. Canvasback carcasses were analyzed for organochlorine pesticides and polychlorinated biphenyls; livers, kidneys, wingbones, and food items (clams) were analyzed for selected heavy metals. Overall, levels of toxicants in Canvasbacks were below those levels known to cause problems in other avian species. However, 10% of the samples appeared to have elevated lead levels based on wingbone residues. Copper and zinc residues were high in Canvasback livers but their potential effects are unknown.

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## EBBA RESEARCH GRANTS

The Eastern Bird Banding Association is sponsoring two $250 Memorial Grants in aid of research using bird banding techniques or bird banding data. The deadline for receipt of applications is 15 March 1980. Applicants should submit a resume of their ornithological or banding background, the project plan, and a budget to the Chairman, EBBA Memorial Grant Committee: Robert C. Leberman, Powdermill Nature Reserve, Star Route South, Rector, Pennsylvania 15677.

## COLONIAL WATERBIRD GROUP MEETING

The Third Annual Meeting of the Colonial Waterbird Group will be held 25–28 October 1979 at the University of Southwestern Louisiana, Lafayette. Field trips to the Gulf Coast are planned, and a *PROCEEDINGS* will be published as in 1978 and 1979. For information on contributing papers, contact P. A. Buckley, North Atlantic Regional Office, National Park Service, 15 State Street, Boston, Massachusetts 02109. Abstracts must be received by 1 September. For information on registration, write to D. McCrimmon, Laboratory of Ornithology, Cornell University, Ithaca, New York 14853.